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THE CULTIVATION OF MUSHROOMS.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., July 5, 1904.

Sir: I have the honor to transmit herewith a paper entitled "The Cultivation of Mushrooms," and to recommend that it be published as a Farmers' Bulletin.

The paper was prepared by Dr. B. M. Duggar, professor of botany in the University of Missouri, and collaborator with the Office of Vegetable Pathological and Physiological Investigations of this Bureau. Under the direction of the Pathologist and Physiologist of this Bureau, Doctor Duggar has been engaged for several years in the investigation of mushroom culture in all of its phases, and great advances have been made, especially in the production of purer and better spawns.

This bulletin will take the place of Farmers' Bulletin No. 53—How to Grow Mushrooms.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE CULTIVATION OF MUSHROOMS.

THE CULTIVATED MUSHROOM.

In the United States the term "mushroom" refers commercially to but a single species (*Agaricus campestris*) of the fleshy fungi, a plant common throughout most of the temperate regions of the world, and one everywhere recognized as edible. From the time of Pliny, and perhaps much earlier, this plant has been sought as an article of diet, and it has been cultivated for many centuries. In the vicinity of Paris it has certainly been cultivated in some quantity since the sixteenth century; and, in paintings of market scenes by old masters of the seventeenth century, a basket of mushrooms frequently finds a place in the composition, thus showing that at that time the sale of mushrooms was generally recognized in a commercial way.

It is unfortunate that this commercial use of the term "mushroom" restricts it to a single species. The erroneous statement is frequently made, therefore, that there is one mushroom, and that all other fleshy fungi are toadstools. In other cases any edible fungus is termed a mushroom, and all of the species not usually eaten are toadstools. It is better to consider all fleshy fungi as mushrooms and to apply special names to species with known qualities. It will be proper, therefore, to speak of *Agaricus campestris* as the cultivated mushroom, although it is very probable that in this country, as well as in foreign countries, several other species of mushrooms will in time be highly prized for cultivation.

The fully expanded plant, or mature mushroom (sporophore), of *Agaricus campestris* (fig. 1) is well known to everyone. It consists of a centrally placed stalk or stipe of from 2 to 6 inches in height, usually not more than 1 inch in diameter, and on the end of this stipe there is borne an umbrella-shaped or cap-shaped portion known as the cap or pileus. The diameter and thickness of this pileus vary greatly in different races or varieties of the cultivated form, and also with the conditions of the environment under which it is produced. The general color of the plant varies in the different varieties from an almost pure white, or cream, to the forms which are deep brown, at least with reference to the upper surface of the cap. The stem is usually cream or white, and bears on its upper extremity near the cap a ring

known as the annulus, which annulus forms a covering and a protecting layer for the delicate under surface of the cap, to the edges of which it was attached previous to the rapid expansion and maturity of the latter. The under surface of the cap is provided with leaflike or gill-like projections, reaching for the most part from the stem to the periphery of the cap. These are termed gills, or "lamellæ." They are constantly pink in color in the white or cream-colored species up to the time of (and sometimes even a day after) the separation of the ring from the cap. Subsequently these gills turn brown and even a deep brownish black. In the brown variety the gills are at first grayish brown, but they also become almost black with age.

As a matter of fact, there are several distinct varieties (or what we may for the present term varieties) of the cultivated mushroom. In

FIG. 1.—*Agaricus campestris*, the cultivated mushroom, common in fields and pastures.

the work thus far done by the writer three varieties have been studied, and based upon color they may be distinguished as a white, a brown, and an intermediate or cream-gray variety. To these have been applied the trade names Alaska, Bohemia, and Columbia, respectively. Under these names the spawns have been distributed to commercial growers.

SPORES AND SPAWN.

If one should take a full-grown mushroom after the under surface of the cap has become exposed by the breaking away of the annulus, twist the stem until it breaks away from its attachment to the cap, or cut it off short, and then place the cap, gill surface downward, on a sheet of white paper, there will be found in the course of twenty-four hours, more or less, a print as illustrated in figure 2. In order to avoid drafts

of air a vessel may be inverted over the preparation. The print obtained is a fairly good reproduction of the projected form of the gills, being composed of a mass of brownish-black powder which has fallen from the gills themselves. The color of this powder corresponds to the color of the gills, and the development of this material is a very important phase in the growth of the mushroom. It is, in fact, for the production of this powdery mass that the mushroom, as we know it, is formed. The brown powder consists of innumerable minute simple cells in the form of ovate bodies, termed "spores." These serve for the reproduction of the mushroom. They are equivalent to the green powdery mass produced by molds which grow upon cheese, bread, and the like. Their function is that of reproducing the mushroom, but they should not be termed seeds. Their structure is so simple and they are in their development so distinct from seeds that a different botanical term should come into general popular use to express this form of reproductive body. Spore is the proper designation for the reproductive bodies of all mushrooms, toadstools, and the like.

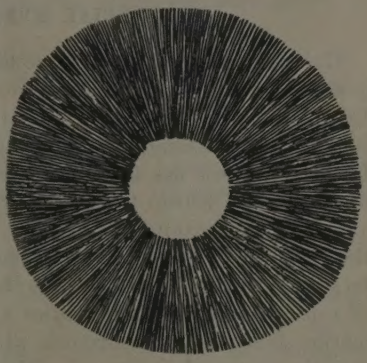

FIG. 2.—A spore print, showing arrangement of gills in the common mushroom.

As a rule, growers do not use these spores directly in growing the cultivated mushroom. Under favorable conditions, however, each minute spore is capable of germination and of producing a threadlike growth, which by subsequent branching and with extensive ramifications may produce in the course of weeks a spider-weblike, or threadlike growth, penetrating the soil, compost, or other substratum upon which the spore happens to have germinated. When this threadlike growth which develops from the spore is of sufficient extent to be readily observed, it is known as "spawn." The spawn is known to the botanist as the "mycelium" of the mushroom, and it represents what may be termed the vegetative stage of the fungus. It may grow to a considerable extent, and during this growth it stores up nutriment. Under favorable conditions there are then formed on threads growing near the surface small pin-head or cushionlike areas of growth. These pin heads represent the earliest visible stages of what we know as mushrooms. With further growth and modifications they become the buttons which we find growing superficially upon the mushroom bed or bursting through the soil. From the pin-head stage

to the fully expanded mushroom there may be represented a period of growth ordinarily requiring at least a week.

It is evident that this lowly organized mushroom plant differs very much from our common cultivated green plants. There are no such organs as root, stem, and leaf, and a well differentiated body is only formed when the mycelial threads have stored up nourishment and are ready to develop the mushroom, or sporophore, which is to bear the reproductive bodies, or spores.

Up to the period covered by the present investigations the spores have seldom been used in a commercial way. The spawn maker has depended upon finding spawn in his pastures, or in his manure piles, or having it appear spontaneously, as it is termed, in prepared beds; and this spawn he has used in the propagation of other spawn by a process which we may liken, perhaps, to that of propagation by cuttings.

COMMERCIAL MUSHROOM GROWING.

The successful cultivation of mushrooms in America has not been so general as in most of the European countries. It is in France and in England that the mushroom industry has been best developed. France is, properly speaking, the home of the present mushroom industry. Unusual interest has been shown in the United States in the growth of mushrooms within the past few years, and it is to be hoped and expected that within the next ten years the industry will develop to the fullest limit of the market demands. The latter will, of course, be stimulated and developed by the increasing popular appreciation of this product. In some cities and towns there is already a good market demand for mushrooms, while in others they may be sold only directly to special customers. This should be borne in mind by prospective growers.

A glance at the figures indicating the quantity of mushrooms passing through the Central Market of Paris will afford a fair idea of the extent of this industry in France. The following tables give approximately the total quantity sold during several successive years and the production by months:

Quantity of mushrooms passing through the Central Market of Paris, 1898–1901.

Year.	Total production.	Immediate consumption.	Amount preserved.	Mean price per pound.
	Pounds.	*Pounds.*	*Pounds.*	*Cents.*
1898	3,960,000	2,200,000	1,760,000	26
1899	6,820,000	4,092,000	2,728,000	26
1900	8,580,000	4,180,000	4,400,000	25
1901	9,680,000	3,740,000	6,160,000	24

Production of mushrooms for the Paris market in 1901, by months.

Month.	Total production.	Month.	Total production.
	Pounds.		*Pounds.*
January	902,000	July	734,800
February	895,400	August	651,200
March	941,600	September	653,400
April	917,400	October	649,000
May	985,600	November	655,600
June	877,800	December	726,000

CAUSES OF FAILURE.

Success in mushroom growing depends on intelligent study of conditions and on experience. While many American growers have been successful in the production of mushrooms, a much larger number have failed. In most cases their failures have been due to one or more of the following causes:

(1) The use of poor spawn, or of spawn which has been killed by improper storage.

(2) Spawning at a temperature injuriously high.

(3) The use of too much water either at the time of spawning or later.

(4) Unfavorable temperature during the growing period.

It is therefore important to the prospective grower that careful attention be given to the general discussion of conditions which follows.

TEMPERATURE AND MOISTURE.

Mushrooms may be grown in any place where the conditions of temperature and moisture are favorable. A shed, cellar, cave, or vacant space in a greenhouse may be utilized to advantage for this purpose. The most essential factor, perhaps, is that of temperature. The proper temperature ranges from 53° to 60° F., with the best from 55° to 58° F. It is unsafe to attempt to grow mushrooms on a commercial basis, according to our present knowledge of the subject, at a temperature much less than 50° or greater than 63° F. Any severe changes of temperature retard growth, or else act injuriously, and many changes of temperature would entirely destroy the profits of the mushroom crop. From this it is evident that in many places mushrooms may not be grown as a summer crop. With artificial heat they may be grown almost anywhere throughout the winter. Moreover, it is very probable that in this country open-air culture must be limited to a few sections, and restricted, commercially at least, to a single season.

A second important factor is that of moisture. The place should not be very damp, or constantly dripping with water. Under such conditions successful commercial work is not possible. A place where it is possible to maintain a fairly moist condition of the atmosphere,

and having such capability for ventilation as will cause at least a gradual evaporation, is, by general practice and by the most extensive experimentation, shown to be necessary. With too rapid ventilation and the consequent necessity of repeated applications of water to the mushroom bed no mushroom crop will attain the highest perfection..

CAVES, CELLARS, AND HOUSES.

Cellars, caves and abandoned mines, or specially constructed houses, (fig. 3) are used for growing mushrooms, because in such places only can the conditions of temperature and moisture be best regulated. Cold is less injurious to mushroom beds than heat. The former renders the bed for a time unproductive; but the latter stimulates the spawn to too rapid growth, which is usually followed by the produc-

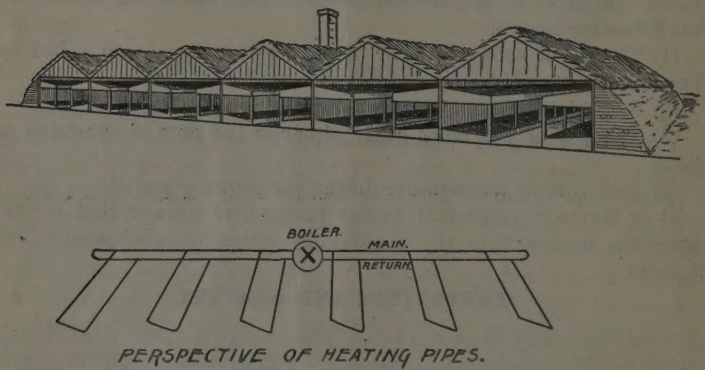

FIG. 3.—A range of mushroom houses, showing heating arrangement and general construction.

tion of unsalable mushrooms, or by the eventual death of the spawn, supposedly by damping off.

Mushrooms may often be grown in a very simply constructed shed or unused barn which will provide against any sudden changes of the temperature, and when it is possible to employ artificial heat the season for mushroom production in such structures may be greatly extended. Cellars are very commonly used in producing mushrooms for family use. Natural or artificial caves are of the first importance, however, for commercial work, since the situation of these below the surface will best insure a temperature throughout almost the entire year more or less close to that which is desired. In selecting caves or cellars, one should guard against the possibility of flooding or of too much seepage water during a rainy season. Perhaps the least satisfactory situation among those mentioned is the greenhouse. Under ordinary circumstances it heats up too readily during days of warm sunshine, and, unless special precautions are taken, it is not to be

generally recommended for amateurs. Nevertheless, during the fall and winter it is possible to grow mushrooms under the benches or in any other unused space with but very little outlay of money or labor. Cold frames may also be used to good advantage during the autumn or spring. The natural caves of this country and abandoned coal mines in some sections should be further investigated with relation to their adaptability for the commercial production of mushrooms. A thorough study should also be made of open air conditions.

In the construction of special mushroom houses any one of a variety of plans may be followed, and the selection of the style will depend, of course, upon its cheapness and efficiency in the particular locality.

PREPARATION OF THE MANURE.

It should be borne in mind that while there are many methods leading to failure there are a number leading to success. In fact, persons succeed in mushroom growing by methods which seem absolutely different. It is essential that the physiological conditions of growth be understood, and then good judgment must be depended upon.

In the growing of mushrooms for commercial purposes, the beds should be constructed of stable manure which has been fermented or composted. Many experiments have been made looking toward the substitution of other composts or waste products for stable manure, but nothing has yet been found which may be more highly recommended. Fresh manure should be obtained, and this should include the litter used for bedding the animals, unless the latter consists of coarse weeds. It is a great mistake, in a commercial way, to attempt to use manure free from straw. Again, stable manure which has been well trampled is nearly always well preserved, and is frequently much richer than any other kind.

The manure should be piled in heaps about 3 feet deep when well pressed down with the fork, and these piles may be of considerable extent. It should be watered until well moistened throughout, but not drenched. In the course of four or five days or a week it will be necessary to fork over or "turn" the manure. A second turning will be required usually in from seven to ten days, and it may be necessary to water again if the material has suffered considerable drying out. If well pressed down and merely moist, the manure will not burn and, moreover, there will be no tendency for a sour fermentation to become established. In from fifteen to twenty-one days, depending upon the conditions, the temperature will begin to fall, the violence of decomposition will begin to show a subsidence, and the compost will be ready for the construction of the beds. The bacteria of rapid decay will become less and less abundant, and finally, when the beds are prepared as subsequently described, the spawn will be able to grow in spite of the bacteria present.

It is the custom with some growers to mix a small quantity of loam, about one-fourth, with the manure. This enables one to use the manure earlier; and, indeed, under such circumstances it may sometimes be used with but little or no composting. Nevertheless, the majority of growers have obtained greater success by the use of the manure alone, and this is also the writer's experience. Very well rotted compost should not be used in mushroom growing if large and solid mushrooms are desired. When sawdust or shavings are employed for bedding the animals, the composting may require a somewhat longer period.

The manure is always ready for the construction of beds when the above conditions have been fulfilled, or when nearly all objectionable odors are lost and a sweet fermentation, as growers term it, has begun.

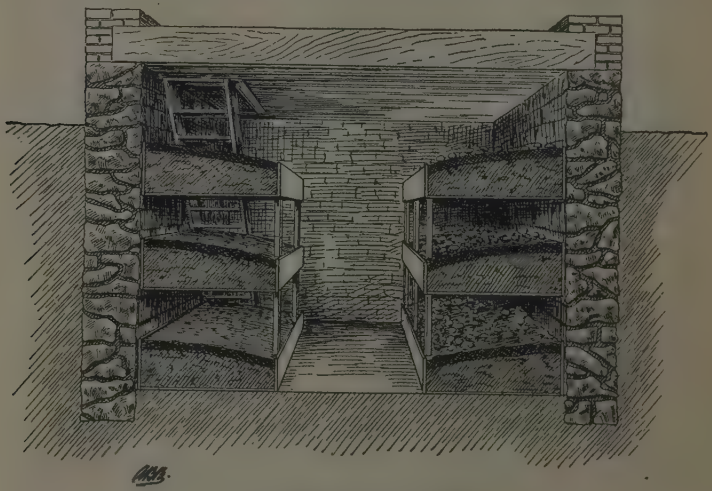

FIG. 4.—Shelf beds in warm cellar.

PREPARING THE BEDS.

Mushroom beds are of two general types, (1) the flat bed, frequently referred to as the English, and (2) the ridge bed, known as the French type. In making the former the entire floor space may be utilized as a bed, and the beds may be arranged in the form of tiers or shelves, as shown in figure 4. In low cellars or caves, and, indeed, wherever the amount of floor space is not the most important consideration, it would be well to avoid the use of shelves; but where the amount of floor space is an important factor they may be adopted to advantage, although the additional labor involved in the growing of a crop under such conditions is an item to be considered. When shelves are used one should be careful to whitewash these after each crop in order to

avoid the increased danger from insect depredations. In any case, flat beds (figs. 4 and 5) should be made from 8 to 10 inches deep.

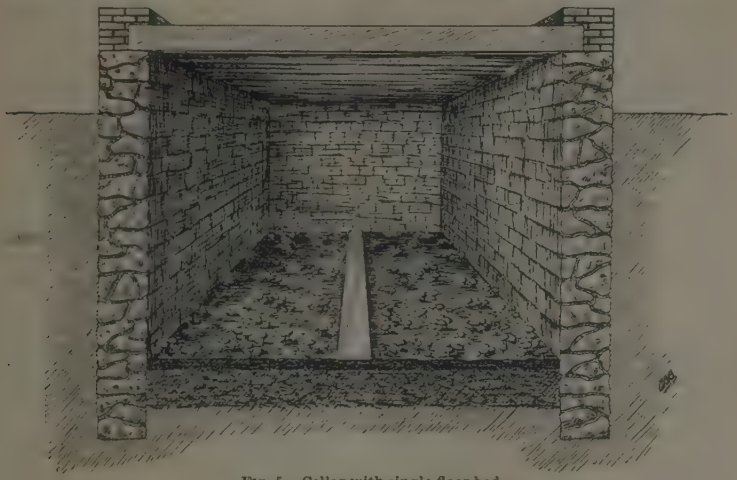

FIG. 5.—Cellar with single floor bed.

Ridge beds (fig. 6) enable one to get a somewhat greater surface space in a given area, but they are also more expensive so far as the

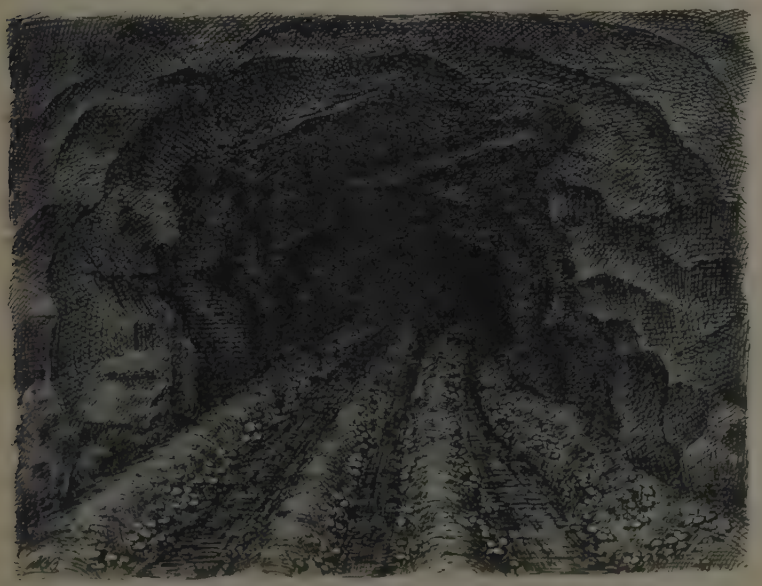

FIG. 6.—Ridge beds in mushroom cave.

labor of construction is concerned. Nevertheless, under many circumstances they are obviously desirable. They should be about 2

feet wide at the base, tapering gradually to the apex, and not more than about 18 to 20 inches high when compressed and cased. The custom is to make two such beds in contact, and then to leave a walk way of 8 or 10 inches between the next two, and so on till the space is occupied. Next to the walls slanting beds may be prepared.

In any case, the manure is made up in the form of the bed desired, and should be firmed or compressed to some extent immediately, in order to prevent drying out and burning when the secondary fermentation takes place. At this time the manure should be neither wet nor dry, but merely moist. The only practical test of the proper moisture content of the manure which can be relied upon is when upon compression water can not readily be squeezed out of it.

SPAWNING.

After the beds are prepared the temperature should be, and it usually will be, too high for spawning. After a sudden rise the temperature should gradually fall during the course of a week or more to about 70° or 75° F. At this temperature spawning may take place, but under absolutely no circumstances should a bed be spawned at a temperature greater than 80° F. If brick spawn is used, the bricks are broken into pieces about 2 inches square, or into from 10 to 12 pieces per brick. These pieces are inserted from 1 to 2 inches below the surface, about 10 inches to 1 foot apart, and the bed is then compressed into final shape. Under the most favorable circumstances it is unnecessary and undesirable to water the beds for several weeks after spawning, or until they are loamed or cased. If they dry out rapidly and some water is necessary, it should be given as a surface spraying, for water in quantity applied to the young spawn will almost invariably cause the latter to damp off.

CASING THE BEDS.

An examination of the bed about two weeks after spawning is desirable, and if it is found that the spawn is "running" the beds may be cased with loam. Casing consists in applying a layer of loam from 1 to 1½ inches deep to the surface of the bed. This loam should have been secured some time in advance and carefully worked over or screened to get rid of the largest pebbles, lumps, and trash. When applied it should be barely moist. Subsequently, if watered at all, it should be merely sprinkled in order to prevent any drying out of the bed. Neither a heavy clay nor a sandy loam should be used for casing purposes, but almost any other soil is good.

WATERING.

As previously indicated, the spreading spawn should receive no water, or, at least, as little as possible. When, however, the mush-

rooms begin to appear, more water will be required, and a light sprinkling may be given once or twice each week or as often as the conditions demand. Beds which come into bearing in proper condition should never be drenched. It has been found by experience that under the most favorable conditions a bed will require occasional sprinkling, since, owing to continual evaporation, there will be a gradual loss of water, at least after the mushrooms begin to appear. Sprinklings should be made after the mushrooms have been gathered, and the loam disturbed by the removal of mushrooms should always receive a light sprinkling.

PICKING AND PREPARING FOR MARKET.

When a bed is in full bearing, the mushrooms should be gathered at least once in two days, and it is well to pick them every day, particularly if the temperature is up to 60° F. or more. Picking is itself an art, and the intelligent grower will soon find that the yield of a bed may be greatly lessened by lack of judgment in picking. To satisfy the general demands of our markets at the present time it is not recommended to take the buttons; yet if there is a fancy trade for these it should be met. Little or no gain of weight occurs in the mushroom, however, after the veil begins to break, so that mushrooms should not be left after this time. Flat tops are a third-grade article, but these, as well as all defective mushrooms, should be sedulously removed from the bed every day.

In picking, grasp the mushroom by the cap (a large one by both cap and stem), twisting it to remove it easily from the soil. Where the mushrooms come up in large united clusters, it will be best to cut them, in order not to disturb the mycelial connections of all. Some good growers practice "cutting" throughout, but the stubs must decay and are a source of danger. After all good mushrooms from a cluster have been taken, remove any fleshy spawn masses adhering and add fresh loam.

As they are picked, the mushrooms are put into shallow baskets and taken to a sorting and packing table. The stems are cut off and any adhering loam is brushed from the cap. It is true that mushrooms keep somewhat better if the stub is left attached and the loam removed by rubbing, but except in special cases this procedure is not to be recommended. It is not necessary to cut the stem off short, but the market demands that there shall be few long shanks.

For the best trade it is desirable to "sort" the mushrooms, placing only those of nearly the same size in the same packages. It is certainly not well to pack together "broilers" and buttons, if this can be avoided. Defective mushrooms should invariably be thrown out. Mushrooms should be treated as a first-grade product in every way,

and therefore the package must be attractive. If the time involved in shipment is not to be very long, they may be put into 5-pound splint-wood baskets (figs. 7 and 8), or they may be packed in 2-pound boxes arranged in crates as prepared for fruit (fig. 9). Shipment may also be made in boxes of sizes demanded by the general or private trade. Baskets afford excellent ventilation, yet boxes are often to be preferred. If the latter are lined with a blue paraffin or oiled paper, a good color contrast will result and the package will be made much more attractive.

FIG. 7.—Basket of mushrooms ready for shipment.

MARKET PRICES.

The prices paid for mushrooms in American markets are unusually variable. Perhaps it is fair to say that one should consider from 35 to 50 cents per pound a good average price. In many cities or towns 30 cents would be as much as could be obtained. On the other hand, a price of 75 cents is frequently paid. The unusual quotation of one dollar or more is not to be expected. It is true that for a fine grade of mushrooms such prices are paid to retailers by the fancy trade and during special seasons or for special occasions. The grower may well look for the time, however, when the market demands will support a generous supply at a constant but fair price.

FIG. 8.—Basket shown in figure 7 when open.

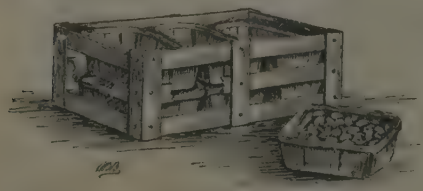

FIG. 9.—A convenient crate for shipping mushrooms.

THE PERIOD OF PRODUCTION.

Under favorable circumstances, a bed may come into bearing within six weeks. It usually requires, however, a longer period, and eight

weeks may more nearly represent the average conditions. If the conditions have been variable, and especially if at times a very low temperature has prevailed, bearing may be still further delayed. Again, the period of production or the profitable "life" of a successful bed may vary greatly, ranging from five weeks to as many months. As a rule, a bed which produces fine heavy mushrooms will bear longer than one which yields plants of lighter weight. Many growers think that there is profit in a bed which yields one-half pound per square foot of surface area. One should not be satisfied with less than this, and if the best conditions prevail this yield is far below what should be obtained. Two pounds per square foot is an excellent yield and some of our growers report this amount. Some of the spawn prepared by the Department of Agriculture has also given a yield equal to this maximum. When the conditions for mushroom growing may be so faithfully reproduced that a yield of two pounds may be made constant, mushrooms may be within the reach of many more persons.

OLD BEDS.

When a bed has ceased to bear, or is no longer profitable commercially, it should be taken down and every particle of the bedding and casing materials removed from the cave, cellar, or house. The manure is still valuable for field and garden purposes, but it is wholly useless and even dangerous for mushrooms because it is not only exhausted with reference to mushroom growing but may also harbor the diseases or enemies of the mushroom. When the bed is removed the house should be thoroughly cleaned, and, if possible, sprayed or fumigated. If conditions remain constant there is then no reason why another crop should not follow immediately.

MUSHROOM ENEMIES.

Under suitable conditions and with the exercise of constant vigilance as to general cleanliness the mushroom bed will seldom fail as a result of diseases or insect depredations. Nevertheless, every precaution should be taken to avoid these difficulties. Some of the most common troubles reported in this country are as follows:

Fogging Off.—During the pin-head or button stage, and sometimes even later, the mushrooms, which may be appearing in quantity, turn brown, cease to grow, and soon decay. This is supposed to be a physiological trouble; that is, one caused by lack of essential conditions. Molds and bacteria may play a secondary part at least in producing this disease. It is most frequent in warm weather.

Black-Spot.—This disease manifests itself by the appearance of small discolored areas on the surface of the cap. It is said to be due to improper watering and to lack of proper ventilation.

Fungous Diseases.—There are several fungous diseases of the mushroom, none of which, however, has been of serious importance in this country, and reference to them may, therefore, be omitted in this place.

Mites.—There are one or two species of mites constantly to be found in compost heaps, which may be injurious in the mushroom bed. They are seldom troublesome at a temperature of less than 59° F., as they are then more or less sluggish; and, although they may be found upon the mushroom, they do little or no harm. At higher temperatures they are supposed to destroy the spawn to a certain extent and, owing to their great numbers, they are at least objectionable upon the mushrooms.

Wood Lice, or "Sow Bugs."—These crustaceans, like the mites, are not of great importance where the conditions of temperature are favorable. The best methods of extermination are by trapping and poisoning them. This may be done by putting pieces of potato smeared with arsenic or Paris green, together with some dry rubbish, into tin cans or boxes placed on the side. Most of the sow bugs that enter these receptacles will be killed by eating the poison.

Snails.—Snails and slugs are frequently pests in mushroom growing, but they may also be readily trapped by the use of lettuce or cabbage leaves.

Springtails.—Springtails may become a source of great annoyance when mushrooms are grown in damp caves. As a rule, they can only establish themselves when carelessness has been shown in cleaning out old bedding material. When once established they multiply very rapidly, and the mushrooms are attacked by them in such numbers that within a day or two every appearance of fogging off is made manifest. These insects may be readily destroyed by fumigation with carbon bisulphid, but prevention is the wiser course.

Larvæ of Flies.—With good manure and under suitable conditions larvæ of mushroom flies are not usually injurious. Nevertheless, the larvæ of the little fly, *Phora minuta*, may be troublesome in warm weather. Fumigation, as previously suggested, may be of service in order that the life of a bed may be extended somewhat later into the warm season.

MUSHROOM SPAWN AND ITS PREPARATION.

In mushroom growing one of the first requisites is that of securing a fresh, reliable spawn. This material is easily injured by even a short period of storage under improper conditions. In the past, small growers have suffered most, as they frequently purchase any spawn which is on the market.

BRICK AND FLAKE SPAWN.

The process of making mushroom spawn, or of spawn manufacture, as it is commonly termed, has unfortunately received very little

attention in this country until recently. Nearly all of the mushroom spawn sold in the American market has been imported. Most of this is grown in England and is put up in the form of bricks or cakes, each brick being about 5½ by 8¼ by 1¼ inches and weighing from 1⅛ to 1¼ pounds (fig. 10). This brick spawn is frequently spoken of merely as English spawn for the reason that the English article is all put up in this form. The making of brick spawn is not usually practiced by the French growers, who use instead a flake spawn. The explanation of this fact may be that a large number of French growers make their own spawn and the brick method is of course more laborious. The flake spawn consists merely of the loose composted material, equivalent to the ordinary bedding material, through which the mycelium of the fungus has grown abundantly. The brick spawn is very compact and easily handled; and, from the experiments which have been made by this Department with the introduction of spawns of various kinds, it would seem to be established that the brick spawn

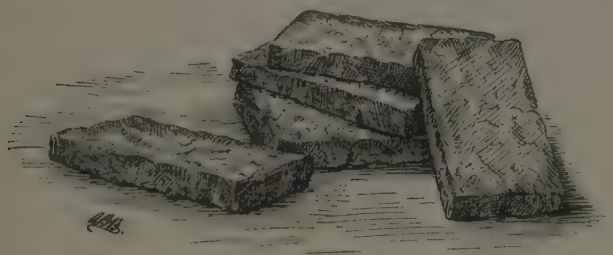

FIG. 10.—English, or brick spawn.

is better fitted to resist the conditions of shipment and subsequent storage. We have, therefore, the curious fact that, although mushroom growing is perfected to the highest degree in France, very little of our imported mushroom spawn comes from that country.

Again, the brick spawn sells at a lower figure than the flake spawn grown by the French. Good flake spawn is, however, such a dense mass of mycelium that as a rule less is required in spawning. The comparative quotations of reliable firms who are agents for this article are as follows:

		Cents per pound.
English brick spawn	1 pound	12 to 30
Do	100 pounds	6 to 15
French flake spawn	2 pounds	15 to 38
Do	100 pounds	10 to 15

The freight rates and import duties add considerably to the price of these articles, which, in quantity, may be purchased much cheaper where made. It is a useless expense to import a material having such bulk as mushroom spawn. There is nothing in the climate to render

the manufacture difficult in America, and good brick spawn is now being made.

When it is recognized that spawn making may go hand in hand with mushroom growing, some growers in this country will doubtless wish to grow the spawn needed in their own work. In such cases the cheaper method of making flake spawn may make it preferable.

VIRGIN SPAWN.

Whether the spawn is made as bricks or as flake material, the point of greatest importance is to secure a so-called virgin spawn, or a new growth of the mycelium of *Agaricus campestris*, which has never exhausted itself to any degree by the production of mushrooms. The problem of securing such virgin spawn is a difficult one, and as usually met in England and France it leaves to chance the quality and other characters of the mushrooms which may grow from such spawn. If, accidentally, mushrooms are found growing on the lawns or in pastures, or if mycelium is located in such situations, small trenches are dug beneath the sod and these are filled with rich manure, with the hope that the vigorous-growing mycelium will penetrate this manure in the course of a few weeks. This usually occurs, and the spawn is said to be very good when one prevents the production of mushrooms by this spawn, and, if possible, by any of the mycelium in the vicinity. When the manure in the trenches is well penetrated by the mycelium, the spawn is removed and dried, and it is usually termed virgin spawn. It may then be used in the inoculation of spawn bricks, or it may be used in the inoculation of small beds, either of which, when penetrated by the growing mycelium, may in turn be used as commercial spawn, brick and flake, respectively, which is then sold or used in a commercial way.

In France, where the demands for virgin spawn are very great, there may be found persons who give their whole time to a search for virgin spawn in the various compost heaps which may be found in the suburbs and throughout the country. These persons readily recognize the spawn of *Agaricus campestris*, or, at least, one is led to believe that they are very adept in such recognition, and this virgin spawn, which is supposed to have resulted from the germination of spores in the compost itself, is sold to mushroom growers at a very high figure. The growers use this spawn in small beds, which, when well penetrated with the mycelium, will be broken up and the contents of the bed dried for general crop purposes. Whether the virgin spawn is obtained in this way or in the manner previously described, it is a haphazard method. The spawn from a bed in full bearing, or that from an old bed, should never be used in a commercial way, for a light crop only may then be expected.

PURE-CULTURE VIRGIN SPAWN.

Artificial Production from Spores.—It will be evident from what has been said that by such methods the exact characteristics of the mushroom which will be grown will not be known, unless a special experiment is made to determine this before the crop is put in. Selection or improvement of the common varieties will, therefore, hardly be possible under such a system. Several years ago it became evident to the writer that, for the development of the mushroom work, there was great need of eliminating the "chance" method of securing a good grade of virgin mushroom spawn. It seemed that this might be accomplished through a knowledge of the conditions under which the spores of *Agaricus campestris* germinated. The Department of Agriculture has given much attention to the investigation of this problem during the past three or four years. The results of the first experiments along this line, conducted by Miss Ferguson, were published in Bulletin No. 16 of the Bureau of Plant Industry. At present it is possible to report greater success and a more practical application of that work. It is now possible by means of chemical stimulation to germinate the spores in quantity under "pure-culture" conditions. Unfortunately, at the present time it can not be said that spore-culture methods are unfailingly successful where the pure-culture precautions are not observed. It is confidently expected, however, that within the course of another year it will be within the reach of any practical and experienced grower to develop spawn from spores of selected mushrooms which he may have grown. By these methods one will be able to select the particular mushrooms from which spores are to be taken, and therefore constant selection and improvement will become possible.

"Tissue-Culture" Method.—Another line of development discovered through work in the Department of Agriculture yielded even better results than the spore-culture process. It may be termed the "tissue-culture" method, and is described as follows: Test tubes or large-mouthed bottles are filled with fresh stable manure or with compost, and after being plugged with cotton these tubes are sterilized, the sterilization being best effected in a steam-pressure apparatus. They can be sterilized, however, by boiling for one-half to one hour in an open vessel of water, but when this process is used a second sterilization should be given on the following day. This will render these tubes of compost perfectly free from all bacterial or fungous contamination. One should then select from the growing bed vigorous, well-flavored mushrooms of a variety or race which has proved to be unusually prolific. The specimens selected should be large enough to indicate that they have the characters desired. The younger the specimen the better, other conditions not being neglected. With a

sterilized scalpel and forceps one may then break off the stem, peel off the outer skin, and remove with great care bits of the tissue of the mushroom without touching any surface which has not been flamed. These bits of tissue may be carefully inserted into the manure in the sterilized tubes. In the course of a week, or sometimes within three days, if no accidental contamination has resulted, these bits of tissue will be found to have sent out a small growth of mycelium. Under favorable conditions this mycelium will spread to all of the material in the tube or bottle in the course of three or four weeks, and it may then be used as pure-culture virgin spawn. These cultures may be made in milk bottles of considerable size; or, once a few tubes have been made, transfers from the mycelium of these may be made to milk bottles containing the sterilized compost, and thus a considerable quantity of an absolutely pure spawn may be produced to serve as inoculation material for bricks or for the flake spawn. It is unfortunate that this method also involves, and must involve, bacteriological precautions. Nevertheless, this process renders it possible to select mushrooms of a given character, or to select toward a given end, with the same certainty with which we may select the seed of other crops commercially grown. Moreover, experiments are now under way which will undoubtedly show that by starting with a few pure cultures this principle may be applied for the production of spawn in quantity.

THE MANUFACTURE OF BRICK SPAWN.

The bricks should be solid and compact and with no cracks or irregularities in the surface. In order to secure bricks of this kind and the best growth of the mycelium, it has been found by experience that a mixture of manure from the cattle shed and from the stable is desirable. This is usually mixed in the proportion of two-thirds of the former to about one-third of the latter, a small quantity of loam being sometimes added. In making the bricks, the material should be somewhat less composted than for making mushroom beds, and it needs to be well selected or raked over, since too much straw in the brick will render it brittle and liable to crack. The mixing of the dried materials is an important process and should be carefully done. The bricks are molded in a frame of the size desired, the material being pounded into the frame by means of a mallet. If one follows the most common method, the bricks are only slightly dried, and then spawned. A piece of virgin spawn is inserted at either end, immediately after which they are rapidly dried before being stacked for the growth of the spawn. By another process the bricks are immediately dried without the insertion of the spawn material, which is later placed in depressions made between two adjacent bricks as they are being stacked for the growth of the spawn. In stacking, the bricks are arranged in layers of one or two bricks in thickness,

depending upon the method of spawning. Upon each layer there is placed a very thin stratum of fresh manure containing a little clean straw. After the layer of manure is added a very slight watering with a rose spray is given. The whole is then covered with clean straw or litter and left for several weeks, when, under favorable conditions, it should be found upon investigation that the spawn has "run" throughout the brick.

Occasional examinations of the bricks should be made, however, where experience is lacking, in order to see that they are not too moist and that the growth may not go too far. When properly made, the bricks should be well penetrated by a moldlike growth of mycelium. A considerable cording or threading of the mycelium indicates unfavorable conditions, or that the growth has progressed too far. The latter usually means that the spawn may not prove as vigorous as desirable.

By the methods above outlined, using pure cultures as virgin spawn, a small amount of spawn for experimental purposes has been made by the Department of Agriculture during the past two years. Under favorable conditions this spawn has given unusual yields. Pure cultures were also furnished two growers who wished to cooperate in the experiment. As a result of this cooperation there was put upon the market in 1903 by practical growers an excellent grade of American brick spawn of "pure-culture" origin. There is every reason to believe that this means a great advance.

There can be no question that spawn made by the method above outlined will be a known product; then, if the mushroom from which cultures were made was properly chosen, there may be constant improvement and selection; and, furthermore, it is believed that the grower will know what to expect or to demand. Pure-culture methods undoubtedly involve some extra expense; but, if in time it may be possible to dispense with the bacteriological precautions, or to make the spawn by direct inoculation of spores into the bricks, then the same result will be accomplished without pure-culture methods and without the additional expense.

It is to be hoped that spawn makers will also adopt for the spawn the trade names suggested, or at least some trade names for the spawn made from the various strains or varieties or from the cultivated mushroom. When purchasing his spawn, the grower should be able to know whether he is obtaining the white (Alaska), the brown (Bohemia), the intermediate cream gray (Columbia), or other similar strains.

It appears to the writer unfortunate that mushroom spawn, at least in brick form, should sell by the pound. Seedsmen and growers alike are interested in reducing weights when the character of the product is not at all affected. It would be better, having well in mind the cubical content of the brick, to sell the spawn by the brick. Of two

bricks differing by half a pound in weight, it may very well be that the lighter is better, owing to the absence of pebbles and of any excess of loam.

STORAGE OF SPAWN.

It is possible to ruin good spawn by improper storage, even in a relatively short period of time. Spawn should be kept in a place that will be both cool and dry, but never hot and dry. This should be remembered by both seedsmen and growers, for many failures may undoubtedly be attributed to the improper storage to which the material has been subjected.

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